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(72) Inventor: Nakayuki Ko

Within Hitachi Institute of Hitachi Seisakusho Co., Ltd., Kuji-cho 4026, Hitachi city, Ibaragi prefecture, Japan

(72) Inventor: Takashi Aoyama

Within Hitachi Institute of Hitachi Seisakusho Co., Ltd., Kuji-cho 4026, Hitachi city, Ibaragi prefecture, Japan

(72) Inventor: Akio Mimura

Within Hitachi Institute of Hitachi Seisakusho Co., Ltd., Kuji-cho 4026, Hitachi city, Ibaragi prefecture, Japan

(72) Inventor: Yoshihiko Koike

Within Hitachi Institute of Hitachi Seisakusho Co., Ltd., Kuji-cho 4026, Hitachi city, Ibaragi prefecture, Japan

(72) Inventor: Yoshiaki Okajima

Within Hitachi Institute of Hitachi Seisakusho Co., Ltd., Kuji-cho 4026, Hitachi city, Ibaragi prefecture, Japan

(71) Applicant: Hitachi Seisakusho Co., Ltd.,

Kanda-Surugadai 4-6, Chiyoda-ku, Tokyo Metropolis, Japan

(74) Patent Attorney: Katsuo Ogawa and two others

Specification

1. Title of the Invention

ENERGY BEAM IRRADIATING METHOD

2. Claims

1. An energy beam irradiating method characterized in that an energy beam spot is irradiated only once to a thin film area for forming a semiconductor active element in a method for annealing many semiconductor active elements formed on an insulating substrate by using an energy beam.

2. An energy beam irradiating method according to claim 1, wherein the energy beam is irradiated such that an overlapping portion of spots of the energy beam is dislocated from the thin film area for forming the semiconductor active element.

3. An energy beam irradiating method according to claim 1, wherein the semiconductor active element is arranged such that an overlapping portion of spots of the energy beam is dislocated from the thin film area for forming the semiconductor active element.

4. An energy beam irradiating method characterized in that an energy beam is irradiated such that a semiconductor active element is arranged in an area having an intensity of $1-1/e^2$ or more of a peak intensity of energy of the energy beam in a method for annealing the semiconductor active element by using the energy beam having a Gaussian distribution.

5. An energy beam irradiating method characterized in that a semiconductor active element is arranged such that the semiconductor active element lies in an area having an intensity of $(1-1/e^2)$ or more of a peak intensity of energy of an energy beam in a method for annealing the semiconductor active element by using the energy beam having a Gaussian distribution.

6. An energy beam irradiating method according to claim 1, wherein the semiconductor active element is divisionally formed and integrated by connection such that an overlapping portion of spots of the energy beam is dislocated from the thin film area for forming the semiconductor active element.

7. An energy beam irradiating method characterized in that a semiconductor active element is divisionally formed and integrated by connection such that the semiconductor active element is arranged in an area having an intensity of $(1-1/e^2)$ or more of a peak intensity of energy of an energy beam in a method for annealing the semiconductor active element by using the energy beam having a Gaussian distribution.

3. Detailed Description of the Invention

[Industrial Field of Application]

The present invention relates to an irradiating method of an energy beam, and particularly relates to an energy beam irradiating method required to manufacture a thin film transistor.

[Prior Art]

For example, as described in Japanese Patent Laid-Open No. 62-31111, when crystalline property is improved by irradiating an energy beam to a thin film on an insulating substrate and annealing the thin film and impurities are activated and the energy beam of a pulse shape is particularly irradiated, a method for removing an unirradiated area is conventionally generally used by overlapping spots of the energy beam at a certain constant width and irradiating the energy beam.

In a method described in Japanese Patent Laid-Open No. 63-10516, when the energy beam having an energy distribution of a double-humped shape is used, the beam anneal is sequentially performed such that one hump of the double-humped beam is approximately overlapped with the other hump of the double-humped beam previously scanned.

[Problems that the Invention is to Solve]

The energy beam has an energy density distribution within the spot of the beam, and the energy density is low in a peripheral portion of the beam spot. Further, a method for irradiating an entire substrate surface by overlapping the beam spots to a certain extent is used at present to remove an inter-beam area. However, when the anneal (e.g., laser anneal) irradiation using the energy beam is once performed, a thin film corresponding to a beam peripheral portion low in the energy density is crystallized, and an area having a crystalline property worse than that of a beam central area is formed. No crystalline property is improved even when the beam is again irradiated (hereinafter, called overlapping irradiation) to this area. Further, a problem of film separation is caused. Furthermore, there is also a problem of ununiformity of the crystalline property. Therefore, no recrystallized film of good quality was obtained.

An object of the present invention is to provide an energy beam irradiating method for obtaining a recrystallized film suitable for the formation of many semiconductor active elements on an insulating substrate.

[Means for Solving the Problems]

The following means are adopted to achieve the above object of the present invention.

A spot diameter (beam diameter) used in the present invention is an effective spot diameter. As shown in Fig. 2, the spot diameter is defined as J times the distance of a position providing $1/e^4$ or 1.83 % of a peak power density intensity of the beam from a beam center (D_L of Fig. 2). Further, an area from a position reduced by $1/e^2$ or 13.5% from the peak power density intensity of the beam, i.e., from a position providing 86.5 % of the peak power density intensity to a position reduced in intensity to $1/e^4$ (or 1.83%) of the beam peak power density intensity is defined as a beam peripheral energy reducing area (25 of Fig. 2).

In a semiconductor active element within a substrate having an array of semiconductor active elements, a position, a diameter and a shape of the energy beam spot are determined in advance to remove ununiformity of recrystallization between the elements such that the above element is completely arranged in an area 26 of Fig. 2 (hereinafter defined and briefly called an energy constant area 26) as an area reduced by $1/e^2$ or 13.5 % from the peak power energy density intensity of the beam, i.e., an area providing 86.5 % or more of the peak energy.

Further, as shown in Fig. 3, the moving amount of a sample or the moving amount of the energy beam (a so-called scan width or scan pitch) is determined in advance to prevent film separation in a portion of the semiconductor active element such that no energy beam spot is overlapped and irradiated to a forming area 23 of the above element in the same crystallization process, i.e., no overlapping portion 24 of the beam spots is overlapped with the above element area 23.

The energy beam is sequentially irradiated and laser anneal is performed such that the above energy reducing area 25 and the above overlapping area 24 of the beam spots are arranged between the above elements.

To achieve the above object, the following second means is adopted.

In the case of the semiconductor active element formed on the insulating substrate such as a peripheral circuit of a liquid crystal display, its area is large. Therefore, there is a case in which the above object cannot be sufficiently achieved by only changes in the diameter and the shape of the energy beam spot and the scan width. Accordingly, the following means is adopted.

As shown in Fig. 7, a circuit having a large area such as a peripheral circuit 71 for driving formed on the insulating substrate is divided such that each divided circuit is arranged in the energy constant area 26 of the above beam spot. The divided peripheral circuit is hereinafter called a divisional peripheral circuit 73.

An irradiating method of the beam in this case will be further described by using Fig. 4. In Fig. 4, it is considered that the semiconductor active element corresponds to the peripheral circuit 71. This semiconductor active element is divided and is set to divisional semiconductor active elements 31. This divisional semiconductor active element corresponds to the divisional peripheral circuit 73 in Fig. 7.

As shown in Fig. 4, the width of an area 33 between the divisional semiconductor active elements is determined in advance such that no overlapping portion 24 of the energy beam spots 22 having an energy intensity distribution shown by reference numeral 21 is overlapped with a forming area of the divisional semiconductor active element 31. After the irradiation of the energy beam, these divisional semiconductor elements 31 are connected to each other by connection 32 so that a final circuit is formed.

[Operation]

When the energy beam is repeatedly irradiated to the same portion of a film on the insulating substrate, transmittance of the film with respect to this beam is improved by first irradiation of the energy beam. Accordingly, a portion near the interface of the film and the substrate is heated by second irradiation. Therefore, the film in this portion is easily separated.

If the above means of the present invention is used, no energy beam is overlapped and irradiated to the film in an area forming the semiconductor active element. Therefore, a preferable recrystallization film providing high crystallization and having no film separation is obtained by selecting suitable incident energy.

Further, in accordance with the present invention, the same energy is approximately irradiated into the semiconductor active element by perfectly arranging the semiconductor active element in the energy constant area so that the same recrystallization effect is obtained within the above element. Thus, a uniform recrystallization film is obtained.

[Embodiment]

One embodiment of the present invention will next be explained by using the drawings. Fig. 5 is a view showing the sectional structure of a thin film transistor for a pixel (hereinafter briefly called TFT) of a liquid crystal display using the present invention. An amorphous silicon film having about 1500 Å in thickness is deposited on a glass substrate 41 as an insulating substrate at a distortion temperature of 580 °C by a low voltage vapor phase growing method (hereinafter called an LPCVD method). A film in an area forming a pixel portion is irradiated by an XeCl pulse excimer laser of 308 nm in wavelength at a peak energy of about 350 mJ/cm^2 and is recrystallized. In this case, a laser irradiating device shown in Fig. 6 was used. A beam spot on a sample substrate surface 57 is formed in a rectangular shape of 2.9 mm (D_L) x 2.5 mm (D_{LL}) in an effective beam area 27, and an energy constant area 26 is set to 2.5 mm (D_e) x 2.1 mm (D_{ee}). The irradiated semiconductor active element 23 has an aperture of 50 μm x 20 μm. The distance between elements is set to 150 μm (11) in leftward and rightward directions, and is set to 450 μm (12) in a vertical direction. As shown in Fig. 1, an element array with respect to the transversal direction is changed to perfectly arrange the above element in the energy constant area 26 of the beam such that the inter-element distance ranges from 150 μm to 300 μm every 18 columns (an n-th column and an (n+18)-th column of Fig. 1). In this example, the width of the overlapping area 24 of the beam spots 22 and the width of the peripheral energy reducing area 25 of the beam are conformed to each other in the transversal direction. This width value is set to 200 μm.

Further, eighteen semiconductor active elements 23 in total are arranged in the energy constant area 26 of the beam spot in the transversal direction.

With respect to the longitudinal direction, it is not necessary to change the above element array since the inter-element distance is large. Five elements 23 in total are arranged in the energy constant area 26 every beam spot 22 in this direction.

In the longitudinal direction, the width of an overlapping area 24a of the spots 22 is set to 250 μm, and the width of a peripheral energy reducing area 25a of the beam spot 22 is set to 200 μm.

As can be seen from Fig. 1, the above element 23 is not arranged in the energy reducing areas 25, 25a and the overlapping areas 24, 24a of the spots 22.

However, in Fig. 1, only one portion of the above actual element is drawn, and the other portions are omitted and described by dotted lines. The laser irradiating spots are partially omitted and described such that the laser irradiating spots correspond to three spots.

The beam scan width (scan pitch) is set to 2.7 mm in the transversal direction, and 2.25 mm in the longitudinal direction.

In the above condition, it has been able to be confirmed that no laser beam is irradiated plural times to one TFT element portion by two-dimensionally repeatedly irradiating the entire substrate surface of the sample stage in the longitudinal and transversal directions. Thus, film separation of the element portion could be prevented. Further, since the dispersion of energy irradiated to all element areas lies within ±6.8 %, a uniform crystallization silicon film is obtained.

Thereafter, an insulating film 45 of SiO_2 having 1000 Å in thickness is formed, and an LPCVD film having 1000 Å in thickness is deposited for a gate electrode 46. The element portion is formed by a photo-etching process, and phosphorus (P) ions are implanted by an ion implantation method such that a dose amount of $5x10^{15}/cm^2$ is provided at 30 KeV in energy. An SiO_2 film for capping having 1000 Å in thickness is formed on this phosphorous layer. Thereafter, impurities are thermally activated for 24 hours at a temperature of 600 °C in source and drain areas 42, 43 of the thin film transistor for a pixel. Thereafter, aluminum (Al) wiring 48 is formed and a transparent electrode constructed by ITO (Inclium Titan Oxyde) is deposited. A pixel portion TFT for a liquid crystal display was formed by the photo-etching process.

Fig. 7 shows another embodiment of the present invention.

Fig. 8 shows a sectional structure of the TFT used in a peripheral circuit portion of the liquid crystal display.

An area forming the peripheral circuit of a film formed in the above embodiment is recrystallized by the following method.

An excimer laser spot (λ=308 nm, peak power intensity 350 nJ/cm^2) having an aperture of 11 mm x 11 mm in the effective beam spot 27 and an aperture of 10 mm x 10 mm in the energy constant area 26 is obtained by an optical system device as shown in Fig. 6 constructed by an optical integrator 53 of Fig. 6 having optical characteristics different from those in the case of a pixel portion, a converging lens 54 and a reduction lens 55.

A peripheral circuit portion 71 of Fig. 7(a) is divided to 9 mm x 9 mm as shown in Fig. 7(b) in conformity with the above spot apertures. The distance 74 between the divisional circuits 73 is set to 2 mm.

Fig. 9 is a view enlarging the peripheral circuit portion of Fig. 7(b). As shown in Fig. 9, the scan pitch is set to 11 mm so as not to overlap the beam spots in this example. Thus, generation of the film separation is prevented. Further, since the beam spot peripheral energy reducing area 25 (0.5 mm in this example) is dislocated from the divisional circuit 73, the dispersion of energy of the laser beam irradiated into the divisional circuit 73 lies within $\pm$6.8 % so that a uniform crystallization silicon film is obtained.

Thereafter, similar to the above embodiment, impurities are activated, and the divisional circuits are then connected to each other by using connection 74 so that a final peripheral circuit is formed.

[Advantage of the Invention]

In accordance with the present invention, the separation of a film for forming the semiconductor active element by irradiating the energy beam and ununiformity of crystallization are removed, and a recrystallization film suitable for the formation of the semiconductor active element can be obtained.

4. Brief Description of the Drawings

Fig. 1 is a view showing an overlapping method of beam spots showing the present invention and the position relation of a semiconductor active element.

Fig. 2 is a view showing an intensity distribution of an energy beam.

Fig. 3 is a view showing an array relation of the energy intensity distribution of the energy beam and the semiconductor active element.

Fig. 4 is a view showing the relation of the energy intensity distribution of the energy beam, its overlapping method and a divisional semiconductor active element.

Fig. 5 is a view showing the sectional structure of a thin film transistor in one embodiment of the present invention.

Fig. 6 is a schematic view of an irradiating device used in the present invention.

Fig. 7 is a view showing an example of a divisional peripheral circuit used in the embodiment.

Fig. 8 is a view showing the section of a thin film transistor in another embodiment of the present invention.

Fig. 9 is a view showing the relation of a dividing method of the peripheral circuit in the embodiment and an irradiating method of the energy beam.

24 --- overlapping area of beam spots, 25 --- beam peripheral energy reducing area, 26 --- energy constant area

DRAWINGS

FIG. 1

23---SEMICONDUCTOR ACTIVE ELEMENT

24---OVERLAPPING AREA OF BEAM SPOTS

25---BEAM PERIPHERAL ENERGY REDUCING AREA

D_e---TRANSVERSAL LENGTH OF ENERGY CONSTANT AREA

D_{ee}---LONGITUDINAL LENGTH OF ENERGY CONSTANT AREA

D_L---TRANSVERAL LENGTH OF EFFECTIVE SPOT AREA

D_{LL}---LONGITUDINAL LENGTH OF EFFECTIVE SPOT AREA

LONGITUDINAL DIRECTION

TRANSVERSAL DIRECTION

FIG. 2

ENERGY

PEAK VALUE OF POWER DENSITY INTENSITY

25 PERIPHERAL ENERGY REDUCING AREA

D_L EFFECTIVE SPOT DIAMETER

27 EFFECTIVE SPOT AREA

26 ENERGY CONSTANT AREA

FIG. 3

DISTANCE

21---ENERGY INTENSITY DISTRIBUTION OF ENERGY BEAM

22---BEAM SPOT

24---OVERLAPPING PORTION OF BEAM SPOTS

FIG. 4

31---DIVISIONAL SEMICONDUCTOR ACTIVE ELEMENT

32---CONNECTION BETWEEN DIVISIONAL SEMICONDUCTOR ACTIVE ELEMENTS

33---AREA BETWEEN DIVISIONAL SEMICONDUCTOR ACTIVE ELEMENTS

FIG. 5

41---GLASS SUBSTRATE

42---SOURCE

43---DRAIN

44---CHANNEL AREA

45---GATE INSULATING FILM

46---GATE ELECTRODE

47---PASSIVATION FILM

48---ALUMINUM ELECTRODE

FIG. 6

51---EXCIMER LASER

52---REFLECTION MIRROR

53---OPTICAL INTEGRATOR

54---CONVERGING LENS

55---REDUCTION LENS

56---SAMPLE SUBSTRATE

57---IRRADIATING AREA PER PULSE

FIG. 7

71 PERIPHERAL CIRCUIT

72 PIXEL PORTION

73 DIVISIONAL PERIPHERAL CIRCUIT

FIG. 9

74 CONNECTION